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(54) Heating unit for inhalation therapy

(57) A heating unit for heating a rising column of liquid and adapted to be secured between a liquid receptacle and a nebulizer comprising, a heating member extending between the receptacle and nebulizer, with the heating member having a channel for passing liquid from the receptacle to the nebulizer. The unit has a device for heating the heating member, and a sensing device for sensing the temperature of the liquid, with the sensing device being mounted in the channel. The heating device is controlled responsive to the sensing device.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patent Rules 1982.

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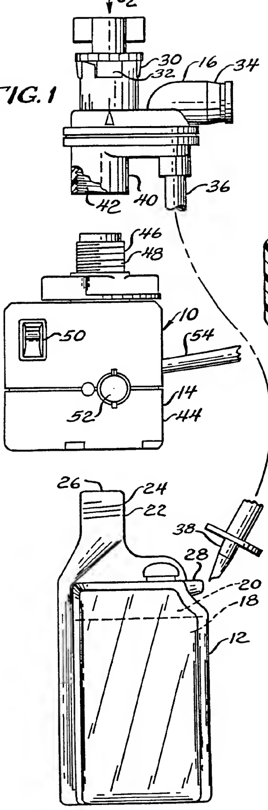
FIG. 1



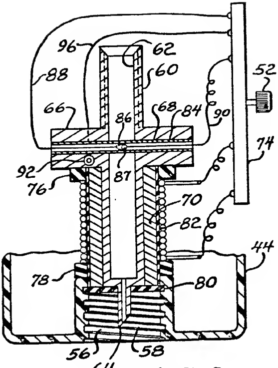


FIG. 2

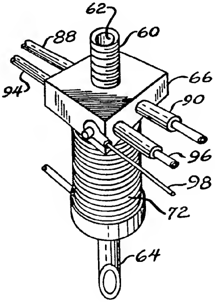


FIG. 3

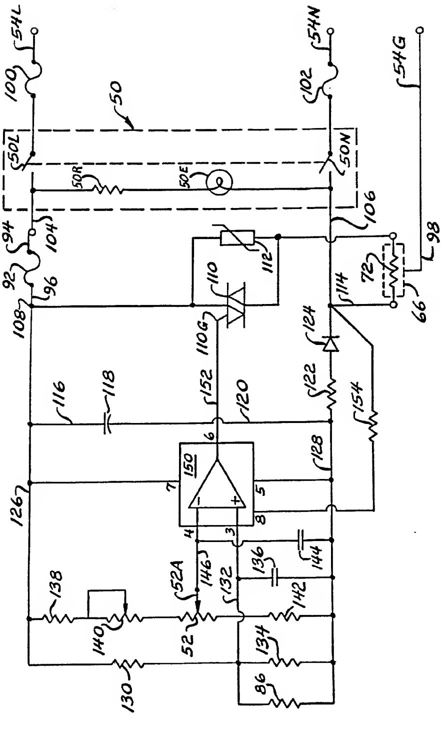

54L
100
50
50L
50R
50E
50N
54N
102
54G
94
104
106
92
96
108
110
112
114
72
98
66
124
110G
122
116
118
152
120
154
150
128
126
7
6
5
8
4
3
52A
146
132
136
144
138
140
52
142
134
130
86

FIG. 4

SPECIFICATION
Heating Unit for Inhalation Therapy

The present invention relates to a heating unit for use in inhalation therapy.

Electric heating units for connection between a receptacle containing sterile water and a nebulizer are known. In such systems, oxygen is passed into the nebulizer where it is mixed with air, and the nebulizer has a venturi to create a low pressure and draw water from the reservoir through the heating unit and into the nebulizer. The heating unit heats the rising column of water, and the nebulizer humidifies the oxygen and air mixture with the heated water, and directs the humidified gas to a patient to perform inhalation therapy.

Prior heating units have been provided with a heating element which has been spaced a substantial distance from the water to be heated, and located on one side of the channel through which the water is passed, resulting in poor heat transfer from the heating element to the water and a temperature gradient across the channel. Also, temperature sensors have been utilized to control desired heating of the water, but the sensors have been spaced a substantial distance from the water channel, and the sensors do not provide a true temperature of the heated water. The following U.S. patents relate to inhalation therapy devices, and are incorporated herein by reference: 3,867,554 3,867,554 3,903,883, 3,915,386, and Re. 30,046. A principal feature of the present invention is the provision of an improved heating unit for use in inhalation therapy.

The heating unit of the present invention heats a rising column of liquid, and is adapted to be secured between a liquid receptacle and a nebulizer. The heating unit comprises, a heating member extending between the receptacle and nebulizer with the heating member having a channel for passing liquid from the receptacle to the nebulizer. The heating unit has means for heating the heating member, means for sensing the temperature of the liquid, and means responsive to the sensing means for controlling the heating means.

A preferred feature of the present invention is that the sensing means is mounted in the channel, and provides an accurate determination of the actual temperature of the liquid in the channel.

Another preferred feature of the invention is that the heating member has an inner elongated core defining the channel, the core preferably being constructed from a material substantially resistant to corrosion by the liquid.

Yet another preferred feature of the invention is that the heating member has an outer sleeve surrounding a portion of the core and constructed from a material having excellent heat transfer properties.

Another preferred feature of the invention is that the heating unit has a heater wire which heats responsive to passage of electricity through the wire, with the wire being wound around a portion of the sleeve such that it heats the liquid through the heating member with lower temperatures than previously required.

A further preferred feature of the invention is the provision of a layer of insulation material interposed between the heating wire and the heating member, with the layer being resistant to absorption of water in order to minimize leakage current from the heater wire.

The invention may be put into practice in various ways and one specific embodiment will be described to illustrate the invention with reference to the accompanying drawings in which:

Figure 1 is a fragmentary exploded view, taken partly in section, of an inhalation therapy device including a heating unit in accordance with the present invention;

Figure 2 is a fragmentary sectional view of the heating unit of Figure 1;

Figure 3 is a perspective view of the heating unit; and

Figure 4 is an electric circuit diagram of the unit of the present invention.

Referring now to Figure 1, there is shown an inhalation therapy device or system generally designated as 10 having a reservoir or receptacle 12, a heating unit 14, and a nebulizer 16. The reservoir 12 has a supply of sterile water 18 retained in a chamber 20 of the reservoir 12. The reservoir 12 has an upper hollow neck 22 having threads 24, and an upper rupturable seal 26. The reservoir 12 also has a rupturable seal 28 located on a side of the reservoir 12. The reservoir 12 may be of the type sold under the trademark Aquapak by Respiratory Care, Inc. of Arlington Heights, Illinois.

The nebulizer 16 is connected to a source of oxygen which passes into an upper portion of the nebulizer 16. The nebulizer 16 has a collar 30 which may be turned to open a window 32 to permit passage of air through the window 32 for mixture with the oxygen. The nebulizer 16 has a venturi which creates a low pressure in order to draw water from the reservoir 12 through the heating unit 14 and into the nebulizer 16, as air through the window 32 for mixture with the oxygen. The nebulizer 16 has a venturi which creates a low pressure in order to draw water from the reservoir 12 through the heating unit 14 and into the nebulizer 16, as will be further discussed below, where the water is utilized to heat and humidify the oxygen and air mixture after the water has been heated by the heating unit 14. The nebulizer 16 directs the heated and humidified gas to a patient through a hollow elbow 34 to perform inhalation therapy. The nebulizer 16 has a conduit 36 communicating between the nebulizer 16 and a hollow outer spike 38. The spike 38 is utilized to rupture the seal 28 in order to establish communication between the conduit 36 and the chamber 20. In use, the nebulizer 16 returns water particles which should not pass to the patient through the conduit 36 and spike 38 to the chamber 20 of the reservoir 12. The nebulizer 16 has a lower annular portion 40 with inner

threads 42, with the lower portion 40 communicating with the inside of the nebulizer 16 for a purpose which will be described below. The nebulizer 16 may be of the type disclosed in U.S. Patents Re. 30,046 or 3,915,386, incorporated herein by reference.

With reference to Figures 1 to 3, the heating unit 14 has an outer casing 44, with the casing 44 having an upper neck 46 with threads 48 which mate with the threads 42 of the nebulizer lower portion 40 in order to secure the heating unit 14 onto the nebulizer 16 to establish fluid communication between the heating unit 14 and nebulizer 16. The casing 44 has an on-off switch 50, and a potentiometer 52 for use in control of the heating unit 14. The heating unit 14 has a cable 54 containing wires which are connected to the inside of the heating unit 14. The casing 44 has a lower bore 56 with inner threads 58 in order to secure the lower portion of the casing 44 onto the threads 24 on the reservoir neck 22 to establish fluid communication between the heating unit 14 and reservoir 12, as will be further described below.

With reference to Figures 2 and 3, the heating unit 14 has an inner elongated core 60 defining a channel 62 extending through the core 60, with the core 60 having a lower sharp hollow piercing member 64 communicating with the channel 62 which ruptures the seal 26 of the reservoir neck 22 when the casing 44 is secured to the reservoir 12 in order to establish fluid communication between the chamber 20 of the reservoir 12 and the channel 62 of the core 60. The core 60 is constructed from stainless steel which is resistant to corrosion by the water passing through the channel 62, and has excellent heat transfer properties. The core 60 has an outwardly directed block 66 having a channel 68 extending therethrough and communicating with the channel 62 for a purpose which will be described below.

The heating unit 14 has an outer sleeve or cylinder 70 surrounding a lower portion of the core 60. The sleeve 70 is constructed from brass which has excellent heat transfer properties. The heating unit 14 has a heater wire 72 wound around the sleeve 70 in helical fashion. The heater wire 72 is of the type which heats responsive to passage of electricity through the wire 72, and opposed ends of the wound wire 72 are connected to a printed circuit board 74 where the wire is electrically connected to a source of electricity to energize the wire 72, as will be further discussed below. The wire 72 may be constructed of any suitable material such as a copper/aluminium compound which heats responsive to passage of electricity through the compound. In a preferred form, the heating unit 14 has a first annular insulation collar 76 located intermediate the wound wire 72 and the block 66, and a second annular insulation collar 78 located intermediate the wound wire 72 and the casing 44. The collars 76 and 78 may be made of any suitable insulation material known to the art.

The heating unit 14 has an elastic gasket 80 surrounding the piercing member 64, and covering a lower end of the core 60 and sleeve 70. The gasket 80 seals against the upper seal 26 of the reservoir 12 when the heating unit 14 is fully threaded and secured onto the reservoir 12 in order to prevent leakage from the reservoir 12 during use of the device 10. The gasket 80 may be made of any suitable elastic material, such as rubber.

The heating unit 14 has a layer 82 of a hydrophobic insulation material located intermediate the heater wire 72 and sleeve 70, with the layer 82 being resistant to absorption of water in order to minimize leakage current from the wire 72. In a preferred form, the layer 82 is constructed from a micro silicone compound.

As shown, the block 66 of the core 60 has an elongated tubular section 84 extending through the channel 68 of the block 66. A temperature sensor 86, such as thermistor, is mounted in the tubular section 84 at a location in the channel 62 for improved sensitivity of the sensor 86 to the temperature of the water passing through the channel 62. The walls of the tubular section 84 are spaced from opposed sides of the channel 62 to permit passage of water in the channel 62 around the tubular section 84. In a preferred form, the sensor 86 is covered by a glass bead 87, and has a pair of opposed conductive leads 88 and 90 connected between the sensor 86 and the board 74.

The heating unit 14 has a thermal fuse 92 of known type mounted in the block 66 in close proximity to the channel 62. The fuse 92 has a pair of conductive leads 94 and 96 connected between the fuse 92 and the printed circuit board 74. The heating unit also has a conductive lead 98 electrically connected to the block 66, and connected to ground.

In use of the device 10, the heating unit 14 is secured to the reservoir 12 and the nebulizer 16 in a manner as previously described by the co-operating threads in order to establish fluid communication between the chamber 20 of the reservoir 12 through the channel 62 of the heating unit 14 and the inside of the nebulizer 16. As previously discussed, during operation the nebulizer 16 creates a low pressure by a venturi to draw water from the chamber 20 of the reservoir 12 through the channel 62 of the heating unit 14 and into the nebulizer 16 to perform inhalation therapy. In accordance with the present invention, electricity is passed through the heater wire 72 in order to heat the wire 72 and the column of water rising through the channel 62 through the sleeve 70 and core 60. The heater wire 72 of the present invention is positioned to heat the water while requiring lower temperatures than the prior devices due to location of the heater wire 72 close to the channel 62. The sensor 86 indicates the temperature of the heated water in the channel 62 to the circuit, and the circuit controls the heater wire 72 in order to maintain the desired temperature as determined by the setting of the potentiometer 52. As previously discussed, the sensor 86 is located in the channel 62 in order to make an accurate determination of the temperature of the heated water. If the device 10 overheats, the fuse 92 melts, and interrupts the passage of electricity through the heater wire 72 in order to terminate operation of the heating unit 14 for safety purposes.

Referring to Figure 4, the electric interconnection of the parts and the operation of the electrical circuit

of the unit 10 will now be discussed in more detail. The cable 54 includes a pair of conductors 54L and 54N which are connected to the conventional electric power lines or mains, with 54N to the neutral. In the United States, this is standardized at a normal 110/120 volt, a.c. The cable 54 also includes a ground wire 54G which is connected to the wire 98 on block 66, which is symbolized by a dashed outline in Figure 4. These lines 54L, 54N, and 54G are preferably connected to a conventional electric three-prong plug and through it to a grounded and polarized receptacle.

Because of the nature of the respiratory care unit, special provisions are made to insure against shock, sparking or overload. Thus, overcurrent fuses 100, 102 are provided, one for each of lines 54L and 54N, prior to the switch unit 50. This switch unit 50 is, as shown, a double-acting type, having two electrical switches 50L and 50N ganged together, to either complete connection from both the lines 54L and 54N or to disconnect both lines from the rest of the circuit. The switch unit also preferably includes a small lamp 50E which is connected through a current-limiting resistor 50R across the output lines 104, 106 from the switch 50. This lamp 50E lights the switch unit (preferably through a red lens) to give a visual warning that the unit 10 is "on" when the switch is depressed to its "on" or closed state.

When the switch unit 50 is closed, the switch 50L connects line voltage from the line 54 through the fuse 100, through the connector 94 to one side of the thermal fuse 92 (which is physically positioned as shown in Figures 2 and 3), and through the line 96 to circuit point 108.

The point 108 is connected to the parallel connection of a Triac 110 and a Varistor 112. The anodes of the Triac 110 are each connected in common with the pins of the Varistor 112, with one of these connections connected to circuit point 108, and the other to the end of the heater wire 72. (The heater wire 72 is, of course, a resistance for electric circuit purposes and is so depicted in Figure 4.)

The other end of the heater wire resistor 72 is connected via a line 114 to the other output line 106 from the switch unit 50.

As thus far described, the circuit of Figure 4 serves to connect the electric power from lines 54L—54N through the fuses 100, 102, the switches 50L, 50N, the fuse 94, the Triac 110 and Varistor 112 to across the heater wire 72. It should thus be appreciated that with the Triac 110 conducting or "on", the line voltage is essentially placed across the heater 72 to power it on.

It should also be appreciated that the Varistor 112 is chosen to have conduction values to protect the Varac from live transmits and thus is a protection device. For normal line voltage, it is essentially an open circuit, so that for normal operating conditions, the status "on" or "off" of the Triac 110 turns "on" or "off" the heater 72.

The Triac 110 is controlled by the voltage applied to its gate 110G from a circuit which will now be described.

The line voltage which is delivered to circuit point 108 is also connected via a line 116 to a capacitor 118. The other side of the capacitor 118 is connected via a line 120 through a resistor 122 to the anode of a diode 124 whose cathode is connected to line 106. This combination of capacitor 118, resistor 122, and diode 124 serves as a half wave rectifier, to develop a d.c. voltage across the capacitor 118 and thus between the lines 126 and 128.

A bridge circuit is formed between lines 126 and 128. This bridge includes a resistor 130 which forms one leg of the bridge and is connected to line 132. A second leg of the bridge is formed by the parallel connection between lines 132 and 128 of the temperature-sensitive resistor 86 (shown physically in Figure 2), a resistor 134 and a capacitor 136.

A third leg of the bridge is formed by the series connection between line 126 of a resistor 138, a trimmer adjustable resistor 140, and the resistance between one end of the potentiometer 52 (also shown in Figures 1 and 2) and its wiper arm 52A. The final leg of the bridge is formed by the resistance of potentiometer 52 from its arm 52A to its other end and a series connected resistor 142, all in parallel connection with a capacitor 144, to line 128.

Shifts in the resistance of the temperature-sensitive resistor 86 produce shifts in the voltage between arm 52A and line 132. This voltage can be adjusted by moving the position of blade 52A in potentiometer 52 (and shifted more permanently by adjusting the trimmer resistor 140).

The bridge output lines 132 and 146 (the latter being connected to the arm 52A) are connected to the inverting and non-inverting inputs (pins 3 and 4 plus and minus) of an operational amplifier 150 connected as a comparator or trigger circuit. Such a circuit produces on its output either one of two levels of voltage d.c., depending on its inputs. When the voltage on pin 4 is greater than that on pin 3, it produces one level, and when pin 3 is greater than pin 4, it produces the other level. The output (pin 6) of the operational amplifier 150 is present on line 152 and is connected to the gate 110G of the Triac 110. The outputs of operational amplifier are such as to either bias the Triac 110 "on" or "off". The V+ input (pin 7) of the operational amplifier 150 is connected to line 136, and its V− input (pin 5) to line 128.

Pin 8 of the operational amplifier 150 is connected through a resistor 154 to the neutral-connected line 106.

As should now be apparent, changes in the temperature of the resistor 86 affect its resistance, so as to shift the voltage between the inputs (3, 4) to the operational amplifier 150. When this resistance change occurs so as to produce an output voltage on line 152, Triac 110 is turned "on" to allow current to flow through the heater resistor 72. This increases the temperature of the *casing* 60a (shown in Figure 2) adjacent to the sleeve 70, increasing the temperature of the liquid taken through the channel 62 and, eventually,

increases the temperature of the resistor 86. When the temperature of the resistor has risen sufficiently, the voltage to the operational amplifier input changes, operational amplifier 150 changes its output on line 152 to gate "off" the Triac 110 and thus turn off the resistance heater 72.

After a time, the temperature-sensing resistor 86 senses the fall in temperature of the liquid in passageway 62 and gates "on" the Triac 110 to restart the cycle.

The capacitors 136 and 144 tend to hold up the voltage levels on the inputs, and this, plus the natural delay caused by the cooling and heating of the metals of sleeve 70 and the core 60, result in a time delay that prevents too-rapid cycling on and off of the heater wire resistor 72. However, the system can maintain the temperature of the rising liquid within close tolerances about a selected value by such repeated cycling because of the close positioning of the temperature-sensing resistor 86 vertically in the flow of the liquid and close upstream of the heating zone.

A prototype of the unit has been constructed and tested and shown to work well. The following circuit values and elements were used in this prototype and are here listed for purposes of a concrete illustration and not for purposes of limitation. It should be clearly understood that the present invention may take many alternative forms and while the following are currently preferred, the present inventor and his assignee may well decide to vary from these in the future, based upon experience and/or considerations of economy.

Elements	Value or Identification
Switch unit 50	Model No. 1855 Mfd. by Marquart
Operational Amplifier 150	UAA 1016
Fuse 100, 102	5×20 mm, 2 amps
Triac 110	TIC 206M
Fuse 92	135°C thermofuse SM135A
Varistor 112	275V 6mm Mfd. by Matushita
Heating wire 72	Cronex AT Extra, nickel, chromium 820 coated with an oxide insulation, at 110 V, 51 turns of .24 mm wire, at 220 V, 102 turns of .15 mm wire at 240 V, 121 turns of .15 mm wire
Potentiometer 52	100K Ohm, linear
Diode 124	IN4005
Trimmer resistor 140	0—25K Ohm, linear
Resistor 86	No. PT55D1 Mfd. by Fenwal, 500K Ohm at 20°C
Resistor 122	12K Ohm
Resistor 130	56K Ohm
Resistor 154	100 Ohm
Resistor 142	150K Ohm
Resistor 138	100K Ohm
Resistor 134	33K Ohm
Capacitor 118	220 microfarad, 25 volts
Capacitors 136, 144	150 microfarad

Although the above values and elements are believed to have been accurately set down, the user is cautioned to verify these by the well-known mathemati

CLAIMS

1. A heating unit for heating a rising column of liquid and adapted to be secured between a liquid receptacle and a nebulizer, comprising:

a heating member adapted to extend between the receptacle and nebulizer, the said heating member having a channel for passing liquid from the receptacle to the nebulizer;

means for heating the heating member;

means for sensing the temperature of the liquid, with the sensing means being mounted in the channel; and

means responsive to the sensing means for controlling the heating means.

2. A heating unit as claimed in claim 1 in which the sensing means comprises a thermistor.

3. A heating unit as claimed in claim 1 or claim 2 including a tubular section extending across the channel, and in which the sensing means is mounted in the tubular section.

4. A heating unit as claimed in claim 3 in which the tubular section is resistant to corrosion.

5. A heating unit as claimed in claim 4 in which the heating unit is constructed from stainless steel.

6. A heating unit as claimed in any one of claims 1 to 5 including a thermal fuse mounted in the heating member in close proximity to the channel, and means responsive to the fuse for terminating operation of the overheating means when the heating unit is overheated.

7. A heating unit for heating a rising column of liquid and adapted to be secured between a liquid receptacle and nebulizer, comprising:

a heating member adapted to extend between the receptacle and the nebulizer, the said heating member having an inner elongated core having a channel for passing liquid from the receptacle to the neublizer, the said core being constructed from a material substantially resistant to corrosion by the liquid, and an outer sleeve surrounding a portion of the core and constructed from a material having excellent heat transfer properties e.g. as good as those of brass; and

means for heating the heating member located adjacent an outer surface of the sleeve.

8. A heating unit as claimed in claim 7 in which the core is constructed from stainless steel.

9. A heating unit as claimed in claim 7 or claim 8 in which the sleeve is constructed from brass.

10. A heating unit as claimed in claim 7, 8 or 9 in which the heating means comprises a wire which heats responsive to passage of electricity through the wire, the said wire being wound around the said sleeve.

11. A heating unit for heating a rising column of liquid and adapted to be secured between a liquid receptacle and nebulizer, comprising:

a heating member adapted to extend between the receptacle and nebulizer, the said heating member having a channel for passing liquid from the receptacle to the nebulizer;

means for heating the heating member comprising a wire which heats responsive to passage of electricity through the wire, the said wire being wound around a portion of the heating member; and

a layer of insulation material interposed between the heating means and the heating member, the said layer being resistant to absorption of water to minimize leakage current from the heating means.

12. A heating unit as claimed in claim 11 in which the layer comprises a mica silicone compound.

13. A heating unit for heating a rising column of liquid and adapted to be secured between a liquid receptacle and a nebulizer, comprising:

an elongated heating member adapted to extend between the receptacle and nebulizer, the said heating member having a channel for passing liquid from the receptacle to the nebulizer and having excellent heat transfer properties e.g. as good as those of brass;

a heater wire which heats responsive to passage of electricity through the wire, the said wire being wound around a portion of the heating member; and

means for electrically energizing the wire to heat the wire and liquid through the heating member.

14. A heating unit as claimed in any one of the preceding claims substantially as specifically described herein with reference to the accompanying drawings.

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